MEMORANDUM

Date: February 4, 1999
To: Jim Bagian, USEPA OMS
From: Tom Wenzel, Robert Sawyer, Lawrence Berkeley National Laboratory
Re: Emission Reduction Potential from Repairing Gross Emitters

This memo describes our analysis of the emissions characteristics of vehicles that never complete I/M testing. These vehicles represent an emissions reduction potential that currently is lost by I/M programs. In this memo we quantify these lost potential emissions reductions, and examine the effect of identifying these vehicles, using remote sensing, and repairing them. Our analysis consists of three steps:

1) compare the emissions of vehicles identified by remote sensing as "gross emitters" with those of "normal emitters";
2) calculate the total potential emission reductions lost by vehicles not completing I/M; and
3) estimate the fraction of these lost emission reduction that can be recovered by identifying these vehicles with remote sensing and repairing them.

The analysis is based on IM240 and remote sensing measurements of 412,000 model year 1981 and newer vehicles, measured in the Phoenix I/M area between January 1996 and June 1997.

Gross vs. Normal Emitters

We first examine the I/M emissions of gross emitters, to determine if they can be repaired down to the same emissions level as normal emitters. We examine 263,000 vehicles with remote sensing measurements prior to their initial I/M test. Of these vehicles, 27,400 (10%) are gross emitters, with at least one remote sensing measurement exceeding 4% CO or 500 ppm HC. We divided the vehicles into 4 groups, based on the result of their I/M testing:

1) vehicles that pass their initial IM240 test;
2) vehicles that fail their initial test, but pass a retest;
3) vehicles that fail their initial test, and fail subsequent testing; and
4) vehicles that fail their initial test and never receive a subsequent test.

Group 3 vehicles should include all vehicles that are waived from meeting IM240 standards, after having made repairs up to the repair cost limit. Technically, these vehicles should be excluded from our analysis, since they legally did not complete the I/M program. However, the number of waived vehicles is quite small, only 54 vehicles over the period studied (to be confirmed by AZ DEQ).

Table 1 shows the distribution of both gross emitting and normal emitting vehicles among these four groups, by vehicle type (passenger cars, light duty trucks less than 6,000 lbs GVW, and light duty trucks 6,000 to 8,000 lbs GVW).

Table 1. Number of Vehicles by Type, Emitter Type, and I/M Result

Type	Emitter Type	Group 1	Group 2	Group 3	Group 4	Total	Disn
Cars	Normal	133,608	8,225	2,379	1,894	146,106	90%
	Gross	10,637	2,819	1,533	1,149	16,138	10%
LDT1	Normal	66,220	2,941	514	471	70,146	89%
	Gross	7,150	1,235	388	326	9,099	11%
LDT2	Normal	18,886	873	114	120	19,993	90%
	Gross	1,566	408	100	68	2,142	10%

Table 2 shows the distribution of vehicles by I/M result. About 9% of cars with "normal" remote sensing emissions (that is, less than 4% CO and 500 ppm HC) fail initial I/M testing, and about two-thirds of those pass their final I/M test. In contrast, nearly 34% of gross emitter cars fail initial I/M testing, with only half of them passing out of the I/M program. There is a similar disparity in normal and gross emitter trucks, although the disparity is not as large as for cars.

Table 2. Distribution of Vehicles by Type, Emitter Type, and I/M Result

Type	Emitter Type	Group 1	Group 2	Group 3	Group 4	Total
Cars	Normal	91%	6%	2%	1%	100%
	Gross	66%	17%	9%	7%	100%
LDT1	Normal	94%	4%	1%	1%	100%
	Gross	79%	14%	4%	4%	100%
LDT2	Normal	94%	4%	1%	1%	100%
	Gross	73%	19%	5%	3%	100%

Figures 1 and 2 show average CO and HC emissions from initial and final I/M testing, for normal and gross emitting cars in each of the 4 groups. On average, gross emitters have higher emissions on their initial I/M test than normal emitters; among cars that fail initial I/M testing, gross emitters have initial emissions nearly twice that of normal emitters. The shaded columns indicate the level of emissions of the final I/M test for each group of vehicles (since vehicles in Groups 1 and 4 have only one I/M test, the "final" test is the same as the initial test). The difference between the clean and shaded columns for each group is the emissions reduction due to the I/M program. In general, cars that fail initial but pass final I/M testing (Group 2) see large reductions in emissions. (Not all of this reduction in emissions can be attributed to vehicle repairs. It is possible that a vehicle that was not properly warmed up, or preconditioned, prior to initial I/M testing was falsely failed, and passed a subsequent I/M test after sufficient preconditioning, with no repairs being made.) Failing cars that receive a second I/M test, but never pass out of the I/M program (Group 3), do show a small reduction in emissions.

Note that for both normal and gross emitters, cars that pass subsequent I/M testing (Group 2) show large average reductions in emissions. However, their emissions are not brought down to the levels of cars that pass their initial I/M test (Group 1). Although Group 2 gross emitters have substantially higher initial emissions than Group 2 normal emitters, their final emissions are only slightly higher. This suggests that gross emitters can be successfully repaired, or at least preconditioned to pass a second I/M test, bringing their emissions down to the level of normal emitters. Analysis of initial and final I/M emissions from light duty trucks 1 and 2 show results similar to those from cars.

Figure 3 shows the same data for NOx from cars. Normal emitters tend to have higher NOx emissions than gross emitters; this is because the definition of gross emitters is based on high CO or HC, and not NOx, remote sensing measurements. CO and HC emissions tend to correlate well, whereas NOx tends to be inversely correlated with CO and HC emissions. For example, nearly half of all CO failures also fail for HC, and 75% of HC failures also fail for CO, while only 25% of NOx failures fail for another pollutant as well. Therefore, it is not surprising that the "normal" emitter group, as defined by remote sensing measurements of CO and HC, includes vehicles with high NOx.

Part of the difference in post-I/M emissions of Group 1 and Group 2 vehicles may be due to different vehicle distributions by model year within each group. Figure 4 shows the distribution of cars by model year by I/M result (because their distributions are nearly identical, Groups 3 and 4 are combined). Group 1 vehicles tend to be much newer than the other vehicles, while Group 2 vehicles are slightly newer than Group 3 and 4 vehicles. Newer vehicles tend to have lower emissions than older vehicles, since they are built to meet tighter certification standards and have accumulated fewer miles. On the other hand, they are subject to tighter cutpoints in the I/M program. Figures 5 and 6 show average CO and HC emissions of gross emitting cars by I/M result and model year. Here we see that the emissions are reduced quite consistently for Group 2 cars across all model years. Final IM240 emissions of Group 2 cars are only slightly higher than emissions from Group 1 cars. (The differences between final IM240 emissions from Group 2 cars and Group 1 car emissions are larger in Figures 1 and 2 because Group 2 cars are substantially older than Group 1 cars). The figures also show the final IM240 emissions of Group 2 normal emitters, for comparison. Final IM240 emissions of Group 2 gross emitters are only slightly higher than those for Group 2 normal emitters.

Total Emission Reduction Potential

To quantify the total emission reduction potential of repairing Group 3 and 4 vehicles in the entire I/M fleet, we compared initial and final IM240 emissions of all 788,000 vehicles receiving their initial I/M test between January 1996 and June 1997. We assumed that the vehicles in Groups 3 and 4 would all be repaired, with their emissions reduced down to the post-I/M level of Group 2. This is an optimistic assumption, since the Group 3 and 4 vehicles have higher initial emissions than the Group 2 vehicles (Figures 5 and 6), and it may not be technically possible to repair

their emissions down to the level of the Group 2 vehicles. We did this calculation by vehicle type and model year, and weighted the resulting emissions by annual vehicle miles traveled (VMT) for each vehicle type, using annual mileage data from Acurex 1997. We converted grams per year to (short) tons per day. Table 3 shows the emission reductions from repairing all 28,000 Group 3 and 4 vehicles in the Phoenix fleet. Initial IM240 emissions were 18.0 tpd HC and 261 tpd CO (these are reductions in tailpipe emissions; all calculations in this paper do not include evaporative HC emissions). Final IM240 emissions for the fleet were 15.6 tpd HC and 223 tpd CO, a 14% decrease attributable to the I/M program. If the Group 3 and 4 vehicles were identified and repaired, emissions would be reduced by an additional 11%, to 13.8 tpd HC and 196 tpd CO. Including the benefit of repairing the Group 3 and 4 vehicles nearly doubles the effectiveness of the I/M program.

Table 3. Emission Reductions in Tons per Day from Repairing All 28,000 Group 3 and 4 Vehicles (All Vehicles=788,000)

	Initial	Final IM240		Groups 3 and 4		Percent Reduction	
	IM240	(Group 2 "Repaired")		Repaired		Final	Groups 3&4
Pollutant	tons/day	tons/day	tons/veh*	tons/day	tons/veh*	IM240	Repaired
Tailpipe HC	18.0	15.6		13.8			
abs. reduction		2.5	0.017	1.8	0.023	14%	11%
cum. reduction				4.3			24%
Tailpipe CO	261	223		196			
abs. reduction		38	0.260	27	0.341	14%	12%
cum. reduction				64			25%

* Divide by 365 days/year to convert tons/vehicle to tons/day/vehicle

Table 3 also shows the emission reductions in terms of total tons per vehicle repaired. Emissions of the 53,000 vehicles that initially failed and were repaired or otherwise passed their final I/M test were reduced on average by 0.017 tons per year HC and 0.26 tons per year CO. The emissions from the 28,000 Group 3 and 4 vehicles, if repaired, would be reduced by 0.023 tons per year HC and 0.341 tons per year CO. The per vehicle emissions reductions are larger for the Group 3 and 4 vehicles than the Group 2 vehicles because their initial emissions are higher, as shown in Figures 5 and 6.

This analysis is based on 788,000 vehicles with a single initial I/M test between January 1996 and June 1997. An additional 70,000 vehicles (9%), with multiple initial I/M tests or that failed visual I/M inspection only, were excluded from the analysis. We also excluded about 173,000 vehicles (20%) with either out of state, temporary, or no license plates. Finally, only about 75% of the vehicles participating in the biennial I/M program were tested during the 18-month period for which we have data. We make the assumption that the sample of vehicles excluded from our analysis is comparable to the vehicles we analyzed. Therefore, the ton per day values in Table 3 need to be adjusted to account for the vehicles not included in this analysis. Table 4 shows that the ton per day values should be increased by a factor of 1.64 to reflect total emissions of the Phoenix IM240 fleet.

Table 4. Calculation of Adjustment Factor to Encompass Entire IM240 Fleet

Number of Vehicles				Percent Additional Vehicles	Cumulative Adjustment Factor
	788,150				
plus	70,371	multiple initial tests and visual failures =	858,521	9%	1.09
plus	173,494	out of state, temporary, or no license plate =	1,032,015	20%	1.31
plus	258,004	tests from late 1997 =	1,290,019	25%	1.64

How Much of Potential Reduction Can Be Achieved?

Table 3 shows that repairing vehicles that do not complete the I/M program can result in large emission reductions. However, what fraction of these vehicles can be identified and successfully repaired? For this analysis we return to the 263,000 vehicles that had remote sensing measurements <u>prior</u> to their initial IM240 test. We calculated the emissions reductions from repairing all Group 3 and 4 vehicles, and only those Group 3 and 4 vehicles that were identified by remote sensing as gross emitters.

As shown in Tables 5 and 6, initial IM240 emissions for the 263,000 were 6 tpd HC and 87 tpd CO. Final IM240 emissions for the fleet were 5.2 tpd HC and 75 tpd CO, a 13% decrease attributable to the I/M program. Table 5 shows the result of identifying and repairing the 3,600 gross emitting Group 3 and 4 vehicles: emissions would be reduced by an additional 5%, to 4.9 tpd HC and 71 tpd CO. Table 6 shows that by repairing all 9,000 of the Group 3 and 4 vehicles, the emissions reduction would be nearly twice as much (11%; 0.6 tpd HC and 8 tpd CO) as repairing just the gross emitters (5%; 0.3 tpd HC and 4 tpd CO). Note that the emissions reductions per vehicle for repairing all Group 2 vehicles, and all Group 3 and 4 vehicles, in Tables 5 and 6 are nearly identical to those for the entire sample in Table 3. The emissions reductions per vehicle for repairing the gross emitters (Table 5; 0.028 tons HC and 0.45 tons CO) are 20% to 30% higher than the reductions per vehicle for repairing all Group 3 and 4 vehicles (Table 6; 0.023 tons HC and 0.33 tons CO).

Table 5. Emission Reductions in Tons per Day from Repairing 3,600 <u>Gross Emitting</u> Group 3 and 4 Vehicles (All Vehicles=260,000)

	Initial IM240	Final IM240 (Group 2 "Repaired")		Groups 3 and 4 Repaired		Percent Reduction	
						Final	Groups 3&4
Pollutant	tons/day	tons/day	tons/veh*	tons/day	tons/veh*	IM240	Repaired
Tailpipe HC	6.0	5.2		4.9			
abs. reduction		0.8	0.017	0.3	0.028	13%	5%
cum. reduction				1.0			17%
Tailpipe CO	87	75		71			
abs. reduction		11	0.248	4	0.450	13%	6%
cum. reduction				16			18%

* Divide by 365 days/year to convert tons/vehicle to tons/day/vehicle

Table 6. Emission Reductions in Tons per Day from Repairing All 9,000 Group 3 and 4 Vehicles (All Vehicles=260,000)

	Initial	Final IM240	Groups 3 and 4	Percent Reduction

Pollutant	IM240 tons/day	(Group 2 "Repaired") tons/day	tons/veh*	Repaired tons/day	tons/veh*	Final IM240	Groups 3&4 Repaired
Tailpipe HC	6.0	5.2		4.6			
abs. reduction		0.8	0.017	0.6	0.023	13%	11%
cum. reduction				1.3			22%
Tailpipe CO	87	75		67			
abs. reduction		11	0.248	8	0.330	13%	11%
cum. reduction				19			22%

* Divide by 365 days/year to convert tons/vehicle to tons/day/vehicle

The distribution of vehicles, emissions, and emission reductions by vehicle type, emitter type, and I/M result are shown in Table 7. The table indicates that "normal" emitters as defined by remote sensing have as much emission reduction potential as gross emitters. For instance, 33% of the total potential HC emission reduction comes from gross emitting cars, whereas 35% comes from normal emitting cars. Table 7 also indicates that the majority of emissions reduction potential comes from cars (68% of HC, 73% of CO) as opposed to light duty trucks (32% of HC, 27% of CO).

In practice, not all gross emitters that do not complete I/M testing would be measured by remote sensing. Of all vehicles studied, 262,000 (64%) had remote sensing measurements after their final IM240, and 6,000 of these do not complete I/M testing. Reducing the emissions of these vehicles down to the final IM240 emissions of Group 2 vehicles results in an emissions reduction of 0.34 tpd HC and 5.0 tpd CO. Of the 262,000 vehicles with post-I/M remote sensing measurements, only 22,000 (8%) were gross emitters, and 2,196 of these did not pass their final IM240. Reducing the emissions of these vehicles results in emission reductions of 0.16 tpd HC and 2.6 tpd CO.

Limitations of This Analysis

The above analysis did not account for two important effects that would affect the emission reduction calculations. First, any repairs made on failing vehicles may not be durable. Analysis of three years of I/M data shows that 40% of vehicles that fail for any pollutant in 1995 fail again in 1997. The percentage of repeat failures ranges from 50% for MY81 vehicles to 10% for MY94 vehicles (Wenzel 1998). Because such a large fraction of vehicles that are supposedly repaired in the first round of I/M fail the second round, much of the emissions reduction quantified immediately after I/M will be lost over time. By ignoring the effect of repeat failures of the same vehicles, our analysis over-estimates the benefits from repairing Group 3 and 4 vehicles.

On the other hand, it is possible that vehicles that never pass I/M are removed from the I/M area, either through resale out of the area or scrappage. In an earlier analysis, we looked at the populations of vehicles seen by remote sensing in multiple periods after each vehicle's final I/M test (Wenzel 1998). The fraction of Group 2 and Group 3/4 vehicles seen by remote sensing decreases the further one gets from the final I/M test. By 6 months after the final I/M test, the Group 3 and 4 portion of

the fleet is reduced by 40%; only one-third of the Group 3 and 4 vehicles are still driven in the I/M area over 15 months after their final I/M test. Because Group 3 and 4 vehicles tend to drop out of the fleet at a greater rate than other vehicles, fewer of these vehicles are available for repair to reduce emissions, and our analysis over-estimates the effect of repairing gross emitters (however, the removal of these vehicles from the I/M area, perhaps as a result of the I/M program, does represent an emission reduction typically not quantified in current evaluations of I/M programs). One would expect that the oldest vehicles are the ones that are being "retired" from the I/M area. However, our analysis indicates that the model year distribution of remote sensing readings 15 months after I/M testing is nearly identical to the distribution of readings immediately after I/M testing (Wenzel 1998).

This analysis was restricted to model year 1981 and newer vehicles tested over 18 months of a biennial I/M program. Three groups of vehicles were not included in the analysis: a) model year 1980 and older vehicles, that receive an idle test rather than an IM240; b) vehicles not scheduled for I/M testing until the second half of 1997; and c) vehicles not participating in the I/M program (either legally registered outside of the I/M area, or not registered). We attempted to account for vehicles in group b), by developing an adjustment factor to increase the ton per day emissions values we calculated. However, the other two groups of unaccounted for would increase the baseline emissions inventory, and could affect the calculated emissions reductions from repairing vehicles that do not complete I/M.

The remote sensing data used in this analysis provides only the license plate of the measured vehicle; to obtain vehicle information, remote sensing records must be matched with IM240 records, by license. Therefore there is no information regarding vehicles measured by remote sensing that do not appear in the IM240 database (groups a and c, described above, as well as out of state vehicles that become registered in the area. In addition, if vehicle owners switch license plates between remote sensing measurement and I/M test, remote sensing readings will be assigned to the wrong vehicle and I/M test result. This should not be a major problem, since in Arizona license plates stay with vehicles, rather than drivers, when a vehicle is sold (in states like Colorado license plates stay with drivers, not vehicles). Remote sensing data could be made more accurate by regularly matching license plates with registration information as the data are collected.

Finally, our analysis only examines the maximum emission reduction potential from the vehicles that do not complete the I/M program. The analysis does not consider if these emissions reductions can actually be achieved through vehicle repair, or whether it would be cost-effective to do so.

Issues for Further Analysis

There are several ways this analysis could be improved to evaluate the effect of repairing vehicles that do not complete I/M. The analysis used a definition of gross emitter as a that exceeded CO or HC remote sensing cutpoints at least once. Further analysis could require at least 2 remote sensing exceedances per vehicle.

There are 356,000 vehicles with at least 2 remote sensing readings either before or after I/M testing; 13,000 of these vehicles exceed the gross emitter cutpoints at least twice. In addition, we could use CO cutpoints only in defining gross emitters; earlier research indicates that there are some potential problems with the HC remote sensing data from Phoenix, including negative readings rounded to zero and many deceleration sites resulting in high HC readings (Wenzel, 1998). Another possibility is to use remote sensing cutpoints that vary by model year, so that more newer vehicles are included as gross emitters eligible for repair.

Since remote sensing does not, and indeed cannot, identify all of the vehicles not completing I/M, another approach would be to subsidize repair on the highest emitters, as measured by IM240 during I/M testing. Higher IM240 cutpoints, either constant or varying by model year, could be established; any vehicle exceeding the cutpoints would be eligible for repair by better trained mechanics. Such an approach would ensure that the highest emitters are identified, and are repaired while they are still participating in the I/M program.

Finally, a more detailed analysis of repair effectiveness could be performed by comparing IM240 emissions of the same vehicle over multiple I/M cycles. Such an analysis would separate vehicles into normal and gross emitters, on the basis of either remote sensing or IM240 emissions, and compare the long-term repair effectiveness of each group.

Conclusions

This analysis indicates that nearly half of the potential reduction in HC and CO emissions from the Phoenix I/M program is lost by not fully repairing vehicles that do not complete I/M testing. Most of the lost emission reductions comes from cars rather than light duty trucks. Only half of the lost emission reductions can be attributed to vehicles with high remote sensing readings; the other half of the lost reductions comes from vehicles with normal remote sensing readings. Only 64% of the vehicles that do not complete I/M were measured by remote sensors after their I/M test, and only 8% of these vehicles were gross emitters. Because normal emitters account for half of the lost emission reductions, it may not be efficient to use remote sensing measurements to identify vehicles eligible for repair assistance.

References

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